

# An Environmental Review of Wineries Over the Last Centuries: From Vernacular to High Tech

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*ABSTRACT: From Egyptians and Phoenicians to our times, the process of making wine and wineries have gone a long way. Primitive wineries were caves found or made in the compact solid ground or special rooms constructed with high inertia materials such as rocks or earth blocks. These type of construction, with design variations, lasted until industrial revolution when new materials, mainly steel and glass sheets, were available for construction promoting bigger, faster and cheaper possibilities for industrial buildings. These changes affected interior temperatures and, as a consequence, mechanical energy consuming systems like serpentine pipes inside tanks controlled temperature during the fermentation process and air conditioned equipment were installed on oak breeding barrels rooms began to be mandatory in wineries. These last decades innovation in wineries materiality went from different types of metal sheets to petrol derived materials such as polymers. As thinner and lighter the building skin, the more important the amount of envelope in contact with the compact solid ground. This paper presents results in envelope characterization by energy flux exchanges and compactness of different constructive solutions for wineries responding to two different concepts: the high tech image (while traditional envelope still host wine production) and new skins (new industrial designs). The three main production stages (fermentation, breeding and storage) are discussed in the light of passive architecture.*

*Keywords: wineries, envelope, traditional skins, new skins.*

## INTRODUCTION

Primitive wineries were caves found or made in the compact solid ground or special rooms constructed with high inertia materials such as rocks or earth blocks. Both solutions presented a full structure of thermal mass resistance and therefore great stability of interior temperatures, crucial for wine production.

Near the village of Areni, in Armenia, archaeologists have unearthed the earliest, most reliable evidence of wine production, dating back 6,100 years. (Figure 1)

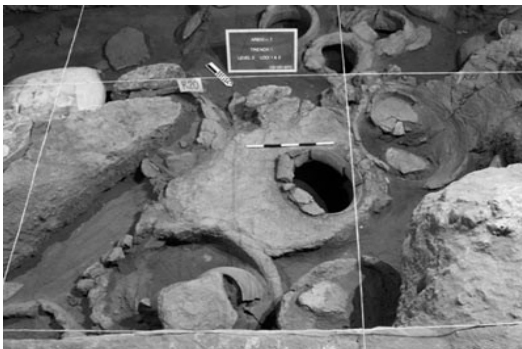


Figure 1. Wine production site in Areni, Armenia

The installation suggests the Copper Age vintners pressed their wine the old-fashioned way, using their feet. Juice from the trampled grapes drained into the vat, where it was left to ferment. The wine was then stored in jars—the cool, dry conditions of the cave would have made a perfect wine cellar. [1] About the best conditions to preserve wine, since the Antiquity Age, wine's temperature sensibility has been known, therefore sun protected constructions were built. In other cases, thick earth blocks were used in deposits, as an example the Rameses II winery, in Tebas. [2] (Figure 2) We know that recipients [containing wine] were placed in cold and dark warehouses. [3]



Figure 2. Rameses II warehouses in Tebas, Egypt

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These last decades innovation in wineries materiality went from different types of metal sheets to petrol derived materials such as polymers. As lighter the building skin, the more important the amount of envelope in contact with the compact solid ground.

The objective of this paper is to present results in envelope characterization by amount of exposed surface and compactness of two different constructive solutions for wineries in the Spanish Rioja Region, classified as 1. The high tech image (while traditional envelope still host wine production) and 2. New skins. (new industrial designs). The three main production stages - fermentation, breeding and storage- are then discussed in the light of passive architecture.

### THE HIGH TECH IMAGE

The high tech image refers to old wineries that, in an effort to renovate, include some signature building related to public activities. This new image does not interfere with the traditional building in which the wine is produced.

Two of the most famous 21<sup>st</sup> century winery images in the Spanish Rioja region are Frank Gehry's dwelling in "Bodegas Marques de Riscal", built with a series of rectilinear elements and clad in sandstone combined with sweeping panels of gold and pink titanium, and mirror finish stainless steel; and Zaha Hadids's steel and glass "Tondonia Pavillion" in "Bodega López de Heredia". (Figures 3 and 4)

Traditionally, the wineries in the region are not open to the public, but as a component of an overall plan to redefine and invigorate its public image, Marques de Riscal commissioned the design of a small building intended to provide a unique experience for visitors to the winery. [4] The building hosts a hotel, a wine tasting room, a restaurant and a conference facility among other amenities. Gehry's building is intended for tourism and marketing. Wine production facilities date primarily from the mid-nineteenth century with thick walls that maintain temperature levels stable.



Figure 3. Frank Gehry's dwelling in Bodegas Marques de Riscal in Elciego, Rioja region, Spain



Figure 4. Wine-tasting pavilion by Zaha Hadid for López de Heredia winery, Rioja region, Spain

In the same line of thinking, high tech Zaha Hadid's wine-tasting pavilion in the López Heredia functions as a tasting room and as a portal to the winery. Zaha Hadid describes it as:

A new bottle for an old wine: a design to safeguard one of López De Heredia's treasures [the winery's elaborately carved mahogany and oak display stand for the 1910 Brussels Worlds Fair]. Originally commissioned as a new pavilion to contain an older pavilion restored from the early 20<sup>th</sup> century, this became a bridge between the past, present and future evolution of its world-famous bodegas. [5]

Wine production is undergone in traditional industrial buildings, some of them dated from the last decades of the 19<sup>th</sup> century to the beginning of the 20<sup>th</sup> century. López de Heredia Winery sticks to the winemaking methods for fermentation and aging established by Rafael López de Heredia, who founded it in 1877. No stainless-steel vats or computer-run temperature controls can be found here. [6]

### López de Heredia Winery

Today the estate covers an area of 53,076 m<sup>2</sup> including 19,718 m<sup>2</sup> of buildings, 3,433. 41 m<sup>2</sup> of which are underground cellars up to 200 metres long and descending to an overall depth of 15 metres. Some 13,000 Bordeaux oak barrels are stored in the heart of a mountain within the cellars. (...) Oak casks play a pivotal role in the fermentation of wines as they use completely natural and traditional methods of wine making. [7]

The buildings stand below and above ground. Main subterranean facility, called “Bodega El Calado” (1892), is excavated out of rock into the mountain and stores wine in barrels between 6 to 10 years. (Figure 8)

Above ground the building called “Bodega Blondeau o cocedero” (boiling ward) where fermentation takes place, was designed so that the wind will keep it naturally fresh, thus avoiding the high temperatures associated with fermentation. [7] (Figure 5)

Also above ground the “Pabellón N°1” (1878) and “Bodega Nueva” (new cellar) (1907) where breeding takes place. “La Bodega Nueva” was one of the first building works undertaken in Spain which used hand-laid concrete (1904). [7] (Figures 6 and 7)



Figure 5. Bodega Blondeau o cocedero. Fermentation.



Figure 6. Pavellón N° 1, 1878. Breeding.



Figure 7. Bodega Nueva, 1907. Breeding.



Figure 8. Bodega El Calado, 1892. Storage.

### NEW SKINS

The new skin concept refers to new wineries built at the end of the 20<sup>th</sup> century or beginning of the 21<sup>st</sup> in which there has been some innovation in their envelope's form and materiality. These buildings are meant for wine production while, at the same time, they tend to create a strong image of the new winery.

One of the most famous new skins in the Rioja region is Calatrava's Ysios Winery (2001). The design main objective was to give a distinctive image to this new label. The building is conceived as an element completely integrated in the surrounding landscape and, at the same time, as an autonomous site-specific sculpture. (Figures 9 and 10)



Figure 9. Calatrava's Bodega Ysios, Laguardia, Rioja Region, Spain.



Figure 10. Curved roof and facades detail. Bodega Ysios

Today the estate covers an area of 72,000 m<sup>2</sup>, 15,384 of which are urbanized, including 8,000 m<sup>2</sup> of buildings. The facility has a capacity of 1.5 million bottles a year and is designed for possible future expansion.

The structure employs laminated wood beams of Scandinavian fir, which span 26 meters between the front and back of the building, rising up and down along the exterior walls in sine curves. Reflective aluminum sheeting serves as the finishing material for the roof. Calatrava finished the south facade with horizontal strips of cedar to match the tonalities of the earth under the vines, and he added a reflecting pool with a mosaic border of broken ceramic tiles that runs the full length of the building. [8] The facade to the north is precast concrete panels with few narrow openings. The eastern and western facades are clad in fret aluminum plates. [9]



Figure 11. Fermentation.



Figure 12. Fermentation



Figure 13. Breeding and Storage

The interior of the winery unfolds in a roughly linear sequence on two levels, with hoppers of grapes entering on the west, two storey fermentation areas (Figures 11 and 12), a breeding and storage central double height space (Figure 13), and finished cases of bottled wine exiting to the east.

Calatrava exposed the utilitarian nature of the interiors, specifying simple materials and finishes and allowing the swooping ceilings and zigzagging walls to provide the visual excitement. [8]

## ENVELOPE CHARACTERIZATION

### Materiality

López de Heredia winery grew into time to conform a series of related buildings. They were built with the latest technology of the time and therefore each cellar has its own personality.

The concrete cover for “La Bodega Nueva” was in fact one of the first private constructions to use reinforced concrete in Spain, and the new cellar was also one of the first places in Spain to use concrete brace beams (1902). [7]

Nevertheless, from underground to innovative concrete slabs, all dwellings are today considered as traditional regarding its heavy materiality and standard constructive technology. (Table 1)

Table 1. Main materials' properties. López de Heredia Winery

	LOPEZ DE HEREDIA WINERY			
	Concrete Slabs	Rock	Earth	Tiles
$\rho$ = Density (Kg/m <sup>3</sup> )	2400	2400	1800	1300
$C_p$ = Specific Heat (J/Kg.K)	805	800	1460	840
$\lambda$ = Thermal Conductivity (W/m.K)	1.63	2.50	2.10	0.49
$s$ = material thickness	0.15	1	0.05	0.05

In Ysios winery, the architect developed a repertoire of dynamic structural forms drawn from history, specifically a family of curves found in the thin-shell concrete vaults of Felix Candela and other engineers in the 1960s [8], giving them a new materiality and meaning.

The North and South walls undulate in plan, which maximizes their stiffness while reducing the thickness of the envelope (but adding insulation) and enlarging the amount of exposed skin to the exterior. As a consequence, reducing thermal mass and increasing energy flux exchanges surface. (Table 2)

Table 2. Main materials' properties. Ysios Winery

	YSIOS WINERY			
	Precast concrete	Laminated wood	Aluminum	Polyurethane
$\rho$ = Density (Kg/m <sup>3</sup> )	2400	530	2700	32
$C_p$ = Specific Heat (J/Kg.K)	805	1600	900	1500
$\lambda$ = Thermal Conductivity (W/m.K)	1.63	0.15	237	0.052
$s$ = material thickness	0.05	0.005	0.0003	0.05

### Energy flux exchanges

To perform a comparison of the conductive heat transfer of the two cases, Fouriers Law Equation (Eq. 1) is used.

$$Q = \lambda * S * (T_e - T_i) / s \quad (1)$$

Where:

$Q$  = flux (W)

$\lambda$  = Thermal Conductivity (W/m.K)

$S$  = Envelope surface (m<sup>2</sup>)

$T_e$  = Exterior temperature (K)

$T_i$  = Interior temperature (K)

$s$  = material thickness (m)

To calculate energy fluxes for the two types of space and compare energy flux exchanges, there will be established two fixed parameters:

$S$  = Envelope surface = 100 m<sup>2</sup>

$\Delta T (T_e - T_i) = 10$  K (except for subterranean cases where  $\Delta T (T_e - T_i) = 0$  K).

The following results were obtained. They show a tendency of the amount of energy flux that will be exchanged:

López de Heredia Winery:

Average Fermentation /Breeding:

Walls  $Q = 4570$  W

Roofs  $Q = 3120$  W

Storage (El Calado):

Walls and Roofs  $Q = 25$  W

Ysios Winery:

Average Fermentation / Breeding / Storage:

Walls  $Q = 1040$  W

Roofs  $Q = 2000$  W

### Exposed envelope

López de Heredia winery has 18% of the envelope underground while Ysios winery maximizes the exposure of the whole above the ground envelope to a 130%. (Figure 14)

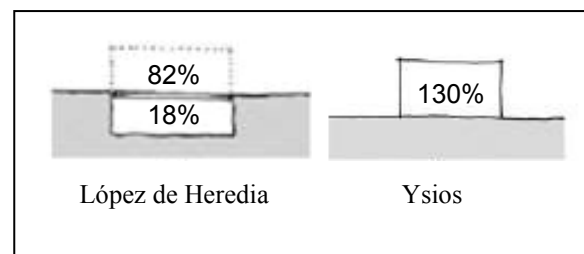


Figure 14. Schemes of exposed envelope for the two wineries in analyses.

Comparison of the compactness of the two cases by using Serra and Coch's compactness coefficient (Eq. 2 and 3) [10].

$$c = S_{eq}/S_G \quad (2)$$

$$c = 4.836 * V_T^{2/3} / S_G \quad (3)$$

Where:

$c$  = compactness coefficient. A-dimensional. Values between 0 and 1, been 1 the compactness coefficient of a sphere.

$S_{eq}$  = equivalent surface

$V_T$  = total volume of the building

$S_G$  = global surface

To calculate compactness for the two different buildings and compare the amount of exposed envelope according with envelope design, there will be established one fixed parameter:  $V_T$  = Total volume of the building = 1000 m<sup>3</sup>

López de Heredia winery  $c = 0.58$

Ysios winery  $c = 0.37$

## DISCUSSION

### Wine climatic needs on each production stage

Temperature and humidity regimes and the principal environmental factors that need to be precisely controlled in the different sites of wineries.

A-Fermentation: on metallic double-skinned tanks.

- Temperature is more important in the containers than in the total dwelling.
- As these casks have a superior opening, CO<sub>2</sub> generated by chemical reactions, that has a higher density than air, descend and accumulates in the inferior part. Therefore inferior ventilation is needed to renovate the air.
- As light can also affect fermentation, therefore it has to be controlled.

B- Breeding: on oak barrels and casks.

In this stage stability within the following reference ranges is very important:

- Air temperature between 12-16 °C and relative humidity between 70-82 %.
- Minimal light. Only when it is absolutely needed.

C-Storage: on glass bottles in cellars.

Of all stages, in this last one inside the building, stability is also a priority. To keep the four microclimatic parameters (temperature, humidity, illumination and ventilation) controlled is essential to obtain the expected result.

### Case analyses

The analysed cases approach to the production needs of wine's industrial process from different perspectives.

While the López de Heredia winery new high tech constructions do not participate in the industrial process itself, it contributes to the renovation of the label. Cellars remain as they were conceived a hundred years ago with massive materials and traditional constructive techniques. Each production stage has a different cellar and therefore envelope performance adjusted to the specific needs. The "Calado" cellar, built underground is the best solution of all, especially for storage.

Ysios winery bets on a new image of the industrial building that will host the production as the visitors. There is no past tradition to preserve, as it is a new brand. The winery is built with an innovative morphology and materiality in an unitary building that must attend all needs with the same envelope. In this case, the storage facility has too much natural light and glass for the recommended microclimatic needs of this production stage. As the envelope thins and expands, the logical conclusion would be a poorer performance, but the use of insulation controls energy flux exchanges.

Assuming a volume of 1000 m<sup>3</sup> López de Heredia winery will have a conductive heat transfer of 19000 W while the Ysios winery will have a value of 12000W in the same conditions with the same volume only considering opaque elements of the envelope.

If we take into account the huge amount of glass of the storage facility in Ysios winery (almost 25% of the envelope of this space), the energy flux exchanges grow enormously in a key production stage glass has a thermal conductivity of 0.96 W/m.K and air filled double glass 4-16-4 has a thermal conductance of 2.7 W/m<sup>2</sup>.K. (Fig. 13).

### Prospective

To continue with this study, thermal inertia and its effects on inside temperature stability will be analysed in the future, as the great performance of insulation to diminish energy exchanges in an expanded envelope will not play the same role in the pursuance of stable temperatures for each stage production.

### ACKNOWLEDGEMENTS.

Authors thank ANPCyT – FONCYT (Argentina) and CA1-ETSAB-UPC (Spain) for funding this research.

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